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Optimised progression rates in soil by means of vibro-impact motion

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Abstract

This piece of work describes an optimised electro-vibroimpact system which has generated impact forces, considerable in relation to its power consumption. Modification has been made to the original mechanism of Nguyen and Woo [1], such that mechanical spring is replaced by a permanent magnet, effectively acting as a highly nonlinear magnetic spring. Consequently, impact forces have been generated to occur at high frequencies, which have proven to be beneficial to a downward progression rate in soil. These rates are compared for increasing diameters of the penetration head. Since the amount of soil resistance increase with this diameter, the consistent progression into soil for the same parameters of input voltage and control frequency confirms the effectiveness of this mechanism for real engineering applications. Practical applications of vibro-impact motion are many and real, and it is thus important to identify an optimised and effective means to use this technology for a minimal amount of energy supply. Nguyen and Woo [1] had developed a new electro-vibroimpact mechanism that is capable of generating large impact forces and achieving fast progression rates on a set of rails with friction. The mechanism uses a solenoid, which is relatively new idea. The oscillations of conductor described by Mendrela and Pudlowski [2, 3] as a linear reluctance self-oscillating motion and Blakley [4] by placing a stop in the path of bar oscillations. Combination of vibration and impact has been proven conducive to a faster progression rate [5, 6]. In this piece of work, the mechanism has been modified and operated to achieve steady progression into a soil medium. The resistive forces from soil could be much larger than dry friction, and future work is directed towards the fracture of rock or brittle material. Hence, there is a need to understand fracture mechanics. Moreover, it is also known that, by varying the dynamics of impact, a more effective progression rate is possible [7]. High frequencies have also been beneficial to such processes [8], which had also been explored earlier [9]. The current setup is capable of high frequency impacts for a minimal amount of energy input, which has been able to achieve steady progression rates in soil.

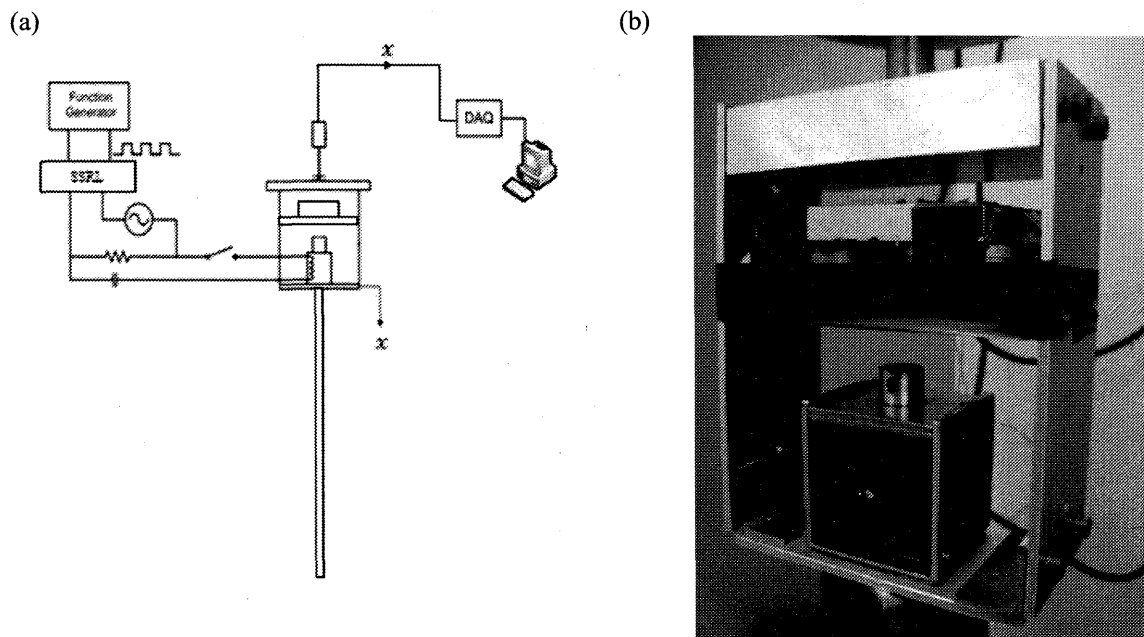


Figure 1. (a) Schematic diagram and (b) Image of the modified system.

Figure 1(a) shows a schematic diagram and 1(b) shows a photograph of the electromechanical system. A permanent magnet was placed at an optimum position such that large impact forces were generated by the conductor on collision with the lower surface. The birth of such dynamics was usually accompanied by a fast frequency of impacts. A set of optimal operating conditions required a specific set of control frequency and input voltage. The position of the permanent magnet is crucial such that its attractive force interacts with the electromagnetic flux of the solenoid so as to induce vibroimpact dynamics producing considerable impact forces. The range of frequencies and voltages within which operation is possible was found to be of 33 to 35 Hz and 40 to 60 V respectively. Continuous oscillation of the

conductor was not possible without the above mentioned ranges. Disruptions to vibroimpact motion were possible when the conductor was attracted upwards to the permanent magnet, resulting in an abrupt end to motion. For the set of parameters investigated, the vibroimpact system will move faster when the oscillation of the bar is stable and exhibits large average magnitudes.

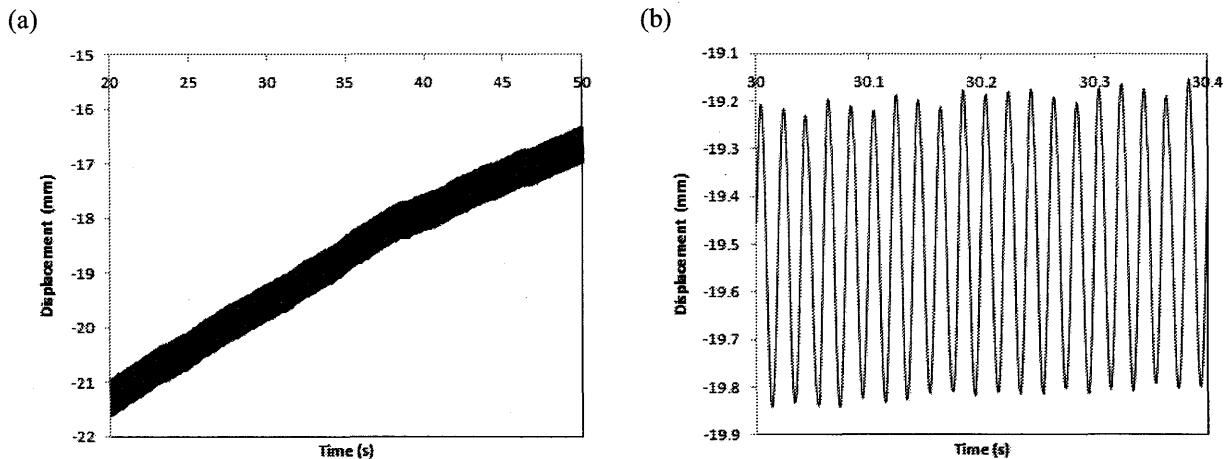


Figure 2. (a) The experimental result of the system displacement and (b) close up view of the displacement. The SSRL control frequency was set at 34.3 Hz and voltage of 50 V.

This newly developed system was observed to being able to penetrate into soil with a steady progression. A frequency range of 33 to 35 Hz was studied in the experiment with an input voltage of 50 V. Based on the experiment, it is observed that the optimum working range of frequency for the system to work efficiently is between 33.3 to 34.3 Hz. Although this is the working frequency range for the system, progression rates vary with frequency value. This is shown in Figure 2. It is observed that the system is capable of steady progression into soil medium. In the close up view Figure 2(b), the system undergoes a repetitive oscillation of three maxima while progressing into the soil. Figure 2 shows the progression rate of the system as 0.1524 mm/s for the control frequency of 34.3 Hz. Separate experiments with stone and brick have proven the effectiveness of mechanism even in the presence of such more difficult resistive forces by virtue of material mechanical properties. The focus of this work is a considerable progression into soil, while being able to maintain such optimal operating conditions by varying electrical parameters.

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